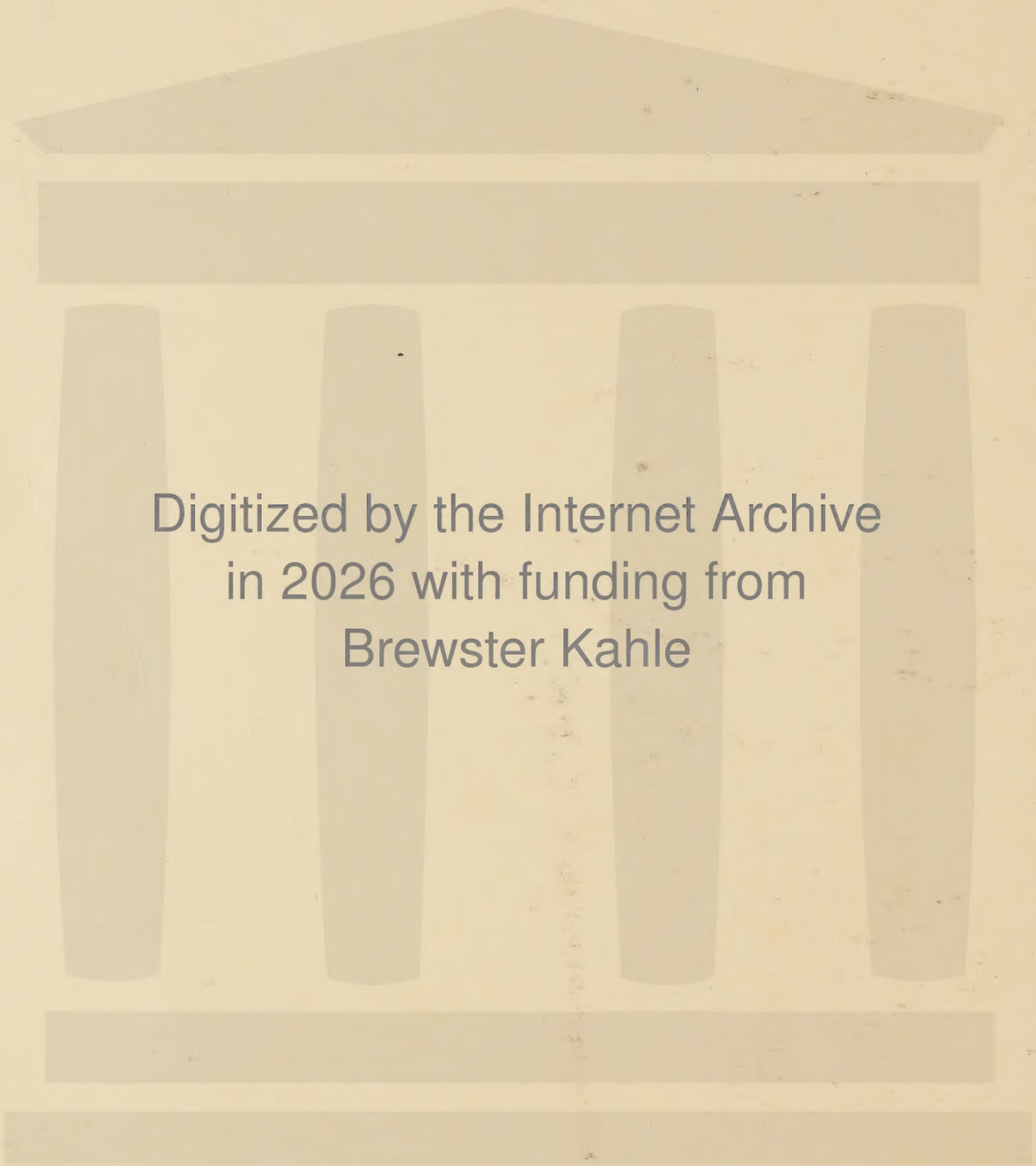


Digitized by the Internet Archive
in 2026 with funding from
Brewster Kahle

https://archive.org/details/referenceacademi00unse

PHYSICAL CONSTANTS

The following lists of physical constants are from the work of B. N. Taylor, W. H. Parker, and D. N. Langenberg (*Reviews of Modern Physics*, July 1969). Their least-squares adjustment of values of the constants depends strongly on a highly accurate (2.4 ppm) determination of e/h from the ac Josephson effect in superconductors, and is believed to be more accurate than the 1963 adjustment which appears to suffer from the use of an incorrect value of the fine structure constant as an input datum. See also NBS Special Publication 344 issued March 1971.

Quantity	Symbol	Value	Error ppm	Prefix	Unit
Speed of light in vacuum	c	2. 997 925 0	0. 33	$\times 10^{8}$	m s^{-1}
Gravitational constant	G	6. 673 2	460	10^{-11}	N m^2 kg^{-2}
Avogadro constant	N_A	6. 022 169	6. 6	10^{26}	kmol $^{-1}$
Boltzmann constant	k	1. 380 622	43	10^{-23}	J K^{-1}
Gas constant	R	8. 314 34	42	10^{3}	J kmol $^{-1}$ K^{-1}
Volume of ideal gas, standard conditions	V_0	2. 241 36	-------	10^{1}	m^3 kmol $^{-1}$
Faraday constant	F	9. 648 670	5. 5	10^{7}	C kmol $^{-1}$
Unified atomic mass unit	u	1. 660 531	6. 6	10^{-27}	kg
Planck constant	h	6. 626 196	7. 6	10^{-34}	J s
	$h/2\pi$	1. 054 591 9	7. 6	10^{-34}	J s
Electron charge	e	1. 602 191 7	4. 4	10^{-19}	C
Electron rest mass	m_e	9. 109 558	6. 0	10^{-31}	kg
		5. 485 930	6. 2	10^{-4}	u
Proton rest mass	m_p	1. 672 614	6. 6	10^{-27}	kg
		1. 007 276 61	0. 08	----------	u
Neutron rest mass	m_n	1. 674 920	6. 6	10^{-27}	kg
		1. 008 665 20	0. 10	----------	u
Electron charge to mass ratio	e/m_e	1. 758 802 8	3. 1	10^{11}	C kg^{-1}
Stefan-Boltzmann constant	σ	5. 669 61	170	10^{-8}	W m^{-2} K^{-4}
First radiation constant	$2\pi hc^2$	3. 741 844	7. 6	10^{-16}	W m^2
Second radiation constant	hc/k	1. 438 833	43	10^{-2}	m K
Rydberg constant	R_∞	1. 097 373 12	0. 10	10^{7}	m^{-1}
Fine structure constant	α	7. 297 351	1. 5	10^{-3}	
	α^{-1}	1. 370 360 2	1. 5	10^{+2}	
Bohr radius	a_0	5. 291 771 5	1. 5	10^{-11}	m
Classical electron radius	r_e	2. 817 939	4. 6	10^{-15}	m
Compton wavelength of electron	λ_C	2. 426 309 6	3. 1	10^{-12}	m
	$\lambda_C/2\pi$	3. 861 592	3. 1	10^{-13}	m
Compton wavelength of proton	$\lambda_{C,p}$	1. 321 440 9	6. 8	10^{-15}	m
	$\lambda_{C,p}/2\pi$	2. 103 139	6. 8	10^{-16}	m
Compton wavelength of neutron	$\lambda_{C,n}$	1. 319 621 7	6. 8	10^{-15}	m
	$\lambda_{C,n}/2\pi$	2. 100 243	6. 8	10^{-16}	m
Electron magnetic moment	μ_e	9. 284 851	7. 0	10^{-24}	J T^{-1}
Proton magnetic moment	μ_p	1. 410 620 3	7. 0	10^{-26}	J T^{-1}
Bohr magneton	μ_B	9. 274 096	7. 0	10^{-24}	J T^{-1}
Nuclear magneton	μ_n	5. 050 951	10	10^{-27}	J T^{-1}
Gyromagnetic ratio of protons in H_2O	γ'_p	2. 675 127 0	3. 1	10^{8}	rad s^{-1} T^{-1}
	$\gamma'_p/2\pi$	4. 257 597	3. 1	10^{7}	Hz T^{-1}
Gyromagnetic ratio of protons in H_2O corrected for diamagnetism of H_2O.	γ_p	2. 675 196 5	3. 1	10^{8}	rad s^{-1} T^{-1}
	$\gamma_p/2\pi$	4. 257 707	3. 1	10^{7}	Hz T^{-1}
Magnetic flux quantum	Φ_0	2. 067 853 8	3. 3	10^{-15}	Wb
Quantum of circulation	$h/2m_e$	3. 636 947	3. 1	10^{-4}	J s kg^{-1}
	h/m_e	7. 273 894	3. 1	10^{-4}	J s kg^{-1}

595-811 O - 75 - 3

Unitless numerical ratios	Value	Error ppm	Prefix
(c^2) kg/eV	5. 609 538	4. 4	10^{35}
(c^2) u/eV	9. 314 812	5. 5	10^{8}
u/kg	1. 660 531	6. 6	10^{-27}
(c^2) m_c/eV	5. 110 041	3. 1	10^{5}
(c^2) m_p/eV	9. 382 592	5. 5	10^{8}
(c^2) m_n/eV	9. 395 527	5. 5	10^{8}
? eV/J	1. 602 191 7	4. 4	10^{-19}
(h^{-1}) eV/Hz	2. 417 965 9	3. 3	10^{14}
$(hc)^{-1}$ eV m	8. 065 465	3. 3	10^{5}
(k^{-1}) eV/K	1. 160 485	42	10^{4}
(hc) $(\text{eV m})^{-1}$	1. 239 854 1	3. 3	10^{-6}
(hc) R_∞/J	2. 179 914	7. 6	10^{-18}
(hc) R_∞/eV	1. 360 582 6	3. 3	10^{1}
(c) R_∞/Hz	3. 289 842 3	0. 35	10^{15}
(hc/k) R_∞/K	1. 578 936	43	10^{5}
m_p/m_e	1. 836 109	6. 2	10^{3}
μ_e/μ_B	1. 001 159 638 9	0. 0031	
μ'_p/μ_B	1. 520 993 12	0. 066	10^{-3}
μ_p/μ_B	1. 521 032 64	0. 30	10^{-3}
μ'_p/μ_n	2. 792 709	6. 2	
μ_p/μ_n	2. 792 782	6. 2	

Other important constants
$\pi = 3.141\ 592\ 653\ 589$
$e = 2.718\ 281\ 828\ 459$
$\mu_0 = 4\pi \times 10^{-7}$ H/m (exact), permeability of free space $= 1.256\ 637\ 061 \times 10^{-6}$ H/m
$\epsilon_0 = \mu_0^{-1} c^{-2}$ F/m, permittivity of free space $= 8.854\ 185 \times 10^{-12}$ F/m

metals (give up ē) — non metal

TABLE OF PERIODIC PROPERTIES OF THE ELEMENTS

Percent Ionic Character of a Single Chemical Bond

Difference in electronegativity	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2
Percent ionic character %	0.5	1	2	4	6	9	12	15	19	22	26	30	34	39	43	47	51	55	59	63	67	70	74	76	79	82	84	86	88	89	91	92

Sub-Atomic Particles

	Electron	Positron	Proton	Neutron	Photon	Neutrino	Meson					Hyperon				
Symbol	e^-, β^-	e^+, β^+	$\uparrow p$	$\uparrow n$	γ	$\uparrow \nu$	$\mu^\pm$	$\pi^\pm$	$\uparrow \pi^0$	$\uparrow K^+$	$\uparrow K^0$	$\uparrow \Lambda^0$	$\uparrow \Sigma^+$	$\uparrow \Sigma^-$	$\uparrow \Xi^-$	Ω^-
Mass*	1	1	1836.12	1838.65	0	~0	206.84	273.23	264.4	966.6	974.4	2181.4	2327.7	2343.2	2584	1686
Charge**	−1	+1	+1	0	0	0	±1	±1	0	+1	0	0	+1	−1	−1	−1
Spin	½	½	½	½	1	½	½	0	0	0	0	½	½-integral	½-integral	½-integral	
Magnetic Moment	1.00 B.m.	1.00 B.m.	2.793 n.m.	−1.913 n.m.	0	~0		0	0							
Mean Life (sec.)	stable	stable	stable	1.11×10^{3}	stable	stable	2.22×10^{-6}	2.54×10^{-8}	$\sim10^{-15}$	$\sim10^{-8}$	$\sim10^{-10}-10^{-7}$	2.8×10^{-10}	$\sim5\times10^{-11}$	$\sim10^{-10}$	$\sim10^{-10}$	$\sim10^{-9}$
Decay Modes				$\rightarrow p+e^-+\bar{\nu}$			$\rightarrow e^\pm+\nu+\bar{\nu}$	$\rightarrow \mu^\pm+\bar{\nu}$	$\rightarrow \gamma+\gamma$; $\rightarrow e^+ + e^- + \gamma$	complex	complex	$\rightarrow p+\pi^-$; $\rightarrow n+\pi^0$	$\rightarrow p+\pi^0$; $\rightarrow n+\pi^+$	$\rightarrow n+\pi^-$	$\rightarrow \Lambda^0+\pi^-$	$\pi^-+\Xi$

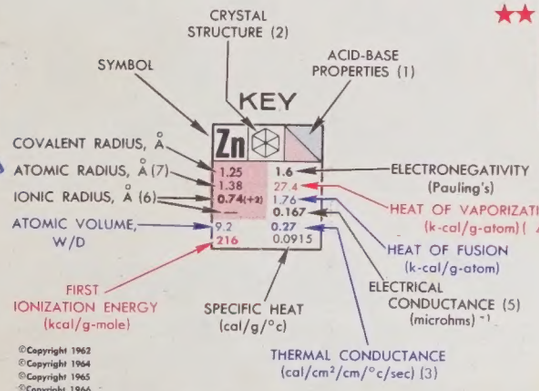
B.m. = Bohr magneton n.m. = Nuclear magneton *In units of 9.1083×10^{-31} kg. **In units of 4.80286×10^{-10} esu. †Exists as an antiparticle not listed.

metals | nonmetals

GROUP IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIII			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
H												B	C	N	O	F	He
Li	Be	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Al	Si	P	S	Cl	Ne
Na	Mg	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	Ga	Ge	As	Se	Br	Ar
K	Ca	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	In	Sn	Sb	Te	I	Kr
Rb	Sr	Ac										Tl	Pb	Bi	Po	At	Xe
Cs	Ba																Rn
Fr	Ra																

★ Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu

★★ Th Pa U NP Pu Am Cm Bk Cf Es Fm Md No Lw



©Copyright 1962
©Copyright 1964
©Copyright 1965
©Copyright 1966
©Copyright 1968 SARGENT-WELCH SCIENTIFIC COMPANY

NOTES:

(1) For representative oxides (higher valence) of group. Oxide is acidic if color is red, basic if color is blue and amphoteric if both colors are shown. Intensity of color indicates relative strength.

(2) Cubic, face centered; cubic, body centered; diamond; cubic; hexagonal; rhombohedral; tetragonal; orthorhombic; monoclinic.

(3) At room temperature. (4) At boiling point. (5) From 0° to 20°C.

(6) Ionic (crystal) radii for coordination number 6.

(7) Metallic radii for coordination number of 12.

SARGENT-WELCH
SARGENT-WELCH SCIENTIFIC COMPANY
7300 LINDER AVENUE, SKOKIE, ILLINOIS 60076
CHICAGO • CINCINNATI • CLEVELAND • DETROIT • DALLAS • DENVER
BIRMINGHAM • SPRINGFIELD, N. J. • ANAHEIM, CALIF. • TORONTO, CANADA

Catalog Number S-18806 SIDE 2

PERIODIC TABLE OF THE ELEMENTS

Table of Radioactive Isotopes

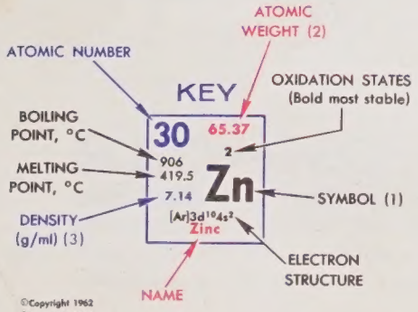
Naturally occurring radioactive isotopes are indicated by a blue mass number. Half lives are in parentheses where s, m, h, d and y stand for seconds, minutes, hours, days and years respectively. The symbols describing the mode of decay and resulting radiation are defined as follows:

α	alpha particle	L	L-electron capture
β^-	beta particle	SF	spontaneous fission
β^+	positron	γ	gamma ray
K	K-electron capture	e^-	internal electron conversion

Ac 227(22y)β^-,α
Ag 110(24s)β^-,γ 111(7.5d)β^-,γ
Am 241(458y)α,γ,e^- 242(16.0h)β^-,K,α,γ 243(8000y)α,γ
As 76(26.7h)β^-,γ 77(39h)β^-,γ
At 210(8.3h)K,α,γ 211(7.2h),Kα,γ
Au 198(2.69d)β^-,γ
Ba 131(12d)K,γ 133(7.2y)K,γ,e^-
Bi 210(5d)β^-,α
Bk 245(4.9d)K,α,γ 249(314d)β^-,α,SF
Br 82(36h)β^-,γ
C 14(5700y)β^-
Ca 41(8x10^{4}y)K 45(165d)β^- 47(4.5d)β^-,γ
Cd 115(43d)β^-,γ
Ce 141(32d)β^-,γ 143(33h)β^-,γ 144(285d)β^-,γ
Cf 246(35h)α,γ,SF 249(360y)α,γ,SF 251(800y)γ
Cl 36(3x10^{5}y)β^-
Cm 243(35y)α,γ 245(9300y)α,γ 247(10^{7}y)
Co 58(71d),K,β^+,γ 60(5.27y)β^-,γ
Cr 51(27d),K,γ
Cs 134(2.0y)β^-,γ 135(3x10^{6}y)β^- 137(30y)β^-,γ
Cu 64(12.8h)K,β^-,β^+,γ
Es 253(20d)α,γ,SF 254(1y)α,SF
Eu 154(16y)β^-,γ 155(1.8y)β^-,γ
Fe 55(2.6y)K 59(45d)β^-,γ
Fm 255(20h)α
Fr 223(22m)β^-,γ,α
Ga 72(14.1h),β^-,γ
Gd 153(236d)K,γ,e^- 159(18h)β^-,γ
Ge 71(11d)K
H 3(12.3y)β^-
Hf 181(45d)β^-,γ,e^-
Hg 197(65h)K,γ,e^- 203(47d)β^-,γ,e^-
Ho 166(27.3h)β^-,γ
I 129(10^{7}y)β^+,γ,e 131(8.05d)β^-,γ
In 114(50d)γ
Ir 192(74.4d)β^-,γ
K 40(10^{9}y)β^+,K,γ 42(12.4h),β^-,γ
La 140(40.2h)β^-,γ
Lu 176(10^{10}y)β^-,K,γ 177(6.8d)β^-,γ
Md 256(90m)K,SF
Mo 99(67h)β^-,γ
Na 22(2.6y)β^+,K,γ 24(15h)β^-,γ
Nd 147(11.1d)β^-,γ
Ni 63(125y)β^- 59(8x10^{4}y),K
Np 237(2.2x10^{6}y)α,γ 239(2.33d)β^-,γ
Os 191(15d)β^-,γ,e^-
P 32(14.2d)β^-
Pa 231(34000y)α,γ
Pb 210(19.4y)β^-,γ,e^- 202(10^{5}y)L
Pd 103(17d)K,γ
Pm 147(2.6y)β^-
Po 210(138.4d)α,γ 209(103y)α,K,γ
Pr 143(13.8d)β^-
Pt 197(18h)β^-,γ
Pu 242(3.8 x 10^{5}y)α,SF 241(13y)β^-,α,γ 239(24300y)α,γ,SF
Ra 226(1620y)α,γ
Rb 86(18.6d)β^-,γ
Re 188(16.7h)β^-,γ 186(3.7d)β^-,γ
Rn 222(3.82d)α
Ru 103(40d)β^-,γ 97(2.9d),K,γ,e^-
S 35(88d)β^-
Sb 122(2.8d)β^-,K,β^+,γ 124(60d)β^-,γ
Sc 46(84d)β^-,γ
Se 75(120 d)K,γ
Sm 153(47h)β^-,γ 145(340d)K,γ
Sn 113(119d)K,L,γ,e^-
Sr 90(28y)β^- 89(51d)β^-,γ 85(64d)K,γ
Ta 182(115d)β^-,γ
Tb 160(73d)$\beta^-\gamma$
Tc 99(2x10^{5}y)β^- 97(10^{6}y)K
Te 127(9.3h)β^-
Th 232(1.4x10^{10}y)α,γ,SF 228(1.91y)β^-
Tl 204(3.81y)β^-,K
Tm 170(134d)β^-,γ,e^-
U 238(4.5x10^{9}y)α,γ,SF 234(2.5x10^{5}y)α,γ,SF 235(7.1x10^{8}y)α,γ,SF 233(1.6x10^{5}y)α,γ
W 185(75d)β^-
Y 90(64h)β^-,e^-
Yb 175(4.2d)β^-,γ 169(31d)K,γ,e^-
Zn 65(245d)K,β^+,γ
Zr 95(65d)β^-,γ,e^- 93(9x10^{5}y)β^-,γ

GROUP IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIII			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1 1.00797 −252.7 −259.2 0.071 1 **H** $1s^1$ Hydrogen																	2 4.0026 −268.9 −269.7 0.126 **He** $1s^2$ Helium
3 6.939 1330 180.5 0.53 **Li** $1s^2\,2s^1$ Lithium	4 9.0122 2770 1277 1.85 2 **Be** $1s^2\,2s^2$ Beryllium											5 10.811 — (2030) 2.34 3 **B** $1s^2\,2s^2\,2p^1$ Boron	6 12.01115 4830 3727 g 2.26 ±4,2 **C** $1s^2\,2s^2\,2p^2$ Carbon	7 14.0067 −195.8 −210 0.81 ±3,5,4,2 **N** $1s^2\,2s^2\,2p^3$ Nitrogen	8 15.9994 −183 −218.8 1.14 −2 **O** $1s^2\,2s^2\,2p^4$ Oxygen	9 18.9984 −188.2 −219.6 1.505 −1 **F** $1s^2\,2s^2\,2p^5$ Fluorine	10 20.183 −246 −248.6 1.20 **Ne** $1s^2\,2s^2\,2p^6$ Neon
11 22.9898 892 97.8 0.97 1 **Na** [Ne]$3s^1$ Sodium	12 24.312 1107 650 1.74 2 **Mg** [Ne]$3s^2$ Magnesium											13 26.9815 2450 660 2.70 3 **Al** [Ne]$3s^2\,3p^1$ Aluminum	14 28.086 2680 1410 2.33 4 **Si** [Ne]$3s^2\,3p^2$ Silicon	15 30.9738 280w 44.2w 1.82w ±3,5,4 **P** [Ne]$3s^2\,3p^3$ Phosphorus	16 32.064 444.6 119.0 2.07 ±2,4,6 **S** [Ne]$3s^2\,3p^4$ Sulfur	17 35.453 −34.7 −101.0 1.56 ±1,3,5,7 **Cl** [Ne]$3s^2\,3p^5$ Chlorine	18 39.948 −185.8 −189.4 1.40 **Ar** [Ne]$3s^2\,3p^6$ Argon
19 39.102 760 63.7 0.86 1 **K** [Ar]$4s^1$ Potassium	20 40.08 1440 838 1.55 2 **Ca** [Ar]$4s^2$ Calcium	21 44.956 2730 1539 3.0 3 **Sc** [Ar]$3d^1 4s^2$ Scandium	22 47.90 3260 1668 4.51 4,3 **Ti** [Ar]$3d^2 4s^2$ Titanium	23 50.942 3450 1900 6.1 5,4,3,2, **V** [Ar]$3d^3 4s^2$ Vanadium	24 51.996 2665 1875 7.19 6,3,2 **Cr** [Ar]$3d^5 4s^1$ Chromium	25 54.938 2150 1245 7.43 7,6,4,2,3 **Mn** [Ar]$3d^5 4s^2$ Manganese	26 55.847 3000 1536 7.86 2, 3 **Fe** [Ar]$3d^6 4s^2$ Iron	27 58.933 2900 1495 8.9 2, 3 **Co** [Ar]$3d^7 4s^2$ Cobalt	28 58.71 2730 1453 8.9 2,3 **Ni** [Ar]$3d^8 4s^2$ Nickel	29 63.54 2595 1083 8.96 2,1 **Cu** [Ar]$3d^{10} 4s^1$ Copper	30 65.37 906 419.5 7.14 2 **Zn** [Ar]$3d^{10} 4s^2$ Zinc	31 69.72 2237 29.8 5.91 3 **Ga** [Ar]$3d^{10} 4s^2 4p^1$ Gallium	32 72.59 2830 937.4 5.32 4 **Ge** [Ar]$3d^{10} 4s^2 4p^2$ Germanium	33 74.922 613* 817 5.72 ±3,5 **As** [Ar]$3d^{10} 4s^2 4p^3$ Arsenic	34 78.96 685 217 4.79 −2,4,6 **Se** [Ar]$3d^{10} 4s^2 4p^4$ Selenium	35 79.909 58 −7.2 3.12 ±1,5 **Br** [Ar]$3d^{10} 4s^2 4p^5$ Bromine	36 83.80 −152 −157.3 2.6 **Kr** [Ar]$3d^{10} 4s^2 4p^6$ Krypton
37 85.47 688 38.9 1.53 1 **Rb** [Kr]$5s^1$ Rubidium	38 87.62 1380 768 2.6 2 **Sr** [Kr]$5s^2$ Strontium	39 88.905 2927 1509 4.47 3 **Y** [Kr]$4d^1 5s^2$ Yttrium	40 91.22 3580 1852 6.49 4 **Zr** [Kr]$4d^2 5s^2$ Zirconium	41 92.906 3300 2468 8.4 5,3 **Nb** [Kr]$4d^4 5s^1$ Niobium	42 95.94 5560 2610 10.2 6,5,4,3,2 **Mo** [Kr]$4d^5 5s^1$ Molybdenum	43 (98) — 2140 11.5 7 **Tc** [Kr]$4d^5 5s^2$ Technetium	44 101.07 4900 2500 12.2 2,3,4,6,8 **Ru** [Kr]$4d^7 5s^1$ Ruthenium	45 102.905 4500 1966 12.4 2,3,4 **Rh** [Kr]$4d^8 5s^1$ Rhodium	46 106.4 3980 1552 12.0 2,4 **Pd** [Kr]$4d^{10} 5s^0$ Palladium	47 107.870 2210 960.8 10.5 1 **Ag** [Kr]$4d^{10} 5s^1$ Silver	48 112.40 765 320.9 8.65 2 **Cd** [Kr]$4d^{10} 5s^2$ Cadmium	49 114.82 2000 156.2 7.31 3 **In** [Kr]$4d^{10} 5s^2 5p^1$ Indium	50 118.69 2270 231.9 7.30 4,2 **Sn** [Kr]$4d^{10} 5s^2 5p^2$ Tin	51 121.75 1380 630.5 6.62 ±3,5 **Sb** [Kr]$4d^{10} 5s^2 5p^3$ Antimony	52 127.60 989.8 449.5 6.24 −2,4,6 **Te** [Kr]$4d^{10} 5s^2 5p^4$ Tellurium	53 126.904 183 113.7 4.94 ±1,5,7 **I** [Kr]$4d^{10} 5s^2 5p^5$ Iodine	54 131.30 −108.0 −111.9 3.06 **Xe** [Kr]$4d^{10} 5s^2 5p^6$ Xenon
55 132.905 690 28.7 1.90 1 **Cs** [Xe]$6s^1$ Cesium	56 137.34 1640 714 3.5 2 **Ba** [Xe]$6s^2$ Barium	57 138.91 3470 920 6.17 3 ★ **La** [Xe]$5d^1 6s^2$ Lanthanum	72 178.49 5400 2222 13.1 4 **Hf** [Xe]$4f^{14} 5d^2 6s^2$ Hafnium	73 180.948 5425 2996 16.6 5 **Ta** [Xe]$4f^{14} 5d^3 6s^2$ Tantalum	74 183.85 5930 3410 19.3 6,5,4,3, 2 **W** [Xe]$4f^{14} 5d^4 6s^2$ Wolfram	75 186.2 5900 3180 21.0 7,6,4,2,−1 **Re** [Xe]$4f^{14} 5d^5 6s^2$ Rhenium	76 190.2 5500 3000 22.6 2,3,4,6,8 **Os** [Xe] $4f^{14} 5d^6 6s^2$ Osmium	77 192.2 5300 2454 22.5 2,3,4,6 **Ir** [Xe]$4f^{14} 5d^7 6s^2$ Iridium	78 195.09 4530 1769 21.4 2, 4 **Pt** [Xe] $4f^{14}$ $5d^9$ $6s^1$ Platinum	79 196.967 2970 1063 19.3 3,1 **Au** [Xe]$4f^{14} 5d^{10} 6s^1$ Gold	80 200.59 357 −38.4 13.6 2,1 **Hg** [Xe]$4f^{14} 5d^{10} 6s^2$ Mercury	81 204.37 1457 303 11.85 3, 1 **Tl** [Xe]$4f^{14} 5d^{10} 6s^2 6p^1$ Thallium	82 207.19 1725 327.4 11.4 4, 2 **Pb** [Xe]$4f^{14} 5d^{10} 6s^2 6p^2$ Lead	83 208.980 1560 271.3 9.8 3,5 **Bi** [Xe]$4f^{14} 5d^{10} 6s^2 6p^3$ Bismuth	84 - (210) — 254 (9.2) 2,4 **Po** [Xe]$4f^{14} 5d^{10} 6s^2 6p^4$ Polonium	85 (210) — (302) — ±1,3,5,7 **At** [Xe]$4f^{14} 5d^{10} 6s^2 6p^5$ Astatine	86 (222) (−61.8) (−71) — **Rn** [Xe]$4f^{14} 5d^{10} 6s^2 6p^6$ Radon
87 (223) — (27) — 1 **Fr** [Rn]$7s^1$ Francium	88 (226) — 700 5.0 2 **Ra** [Rn]$7s^2$ Radium	89 (227) — 1050 — 3 ★★ **Ac** [Rn]$6d^1 7s^2$ Actinium	104														

★	58 140.12 3468 795 6.67 3,4 **Ce** [Xe]$4f^2 5d^0 6s^2$ Cerium	59 140.907 3127 935 6.77 3,4 **Pr** [Xe] $4f^3 5d^0 6s^2$ Praseodymium	60 144.24 3027 1024 7.00 3 **Nd** [Xe] $4f^4 5d^0 6s^2$ Neodymium	61 (147) — (1027) — 3 **Pm** [Xe] $4f^5 5d^0 6s^2$ Promethium	62 150.35 1900 1072 7.54 3,2 **Sm** [Xe] $4f^6 5d^0 6s^2$ Samarium	63 151.96 1439 826 5.26 3,2 **Eu** [Xe] $4f^7 5d^0 6s^2$ Europium	64 157.25 3000 1312 7.89 3 **Gd** [Xe]$4f^7 5d^1 6s^2$ Gadolinium	65 158.924 2800 1356 8.27 3,4 **Tb** [Xe]$4f^9 5d^0 6s^2$ Terbium	66 162.50 2600 1407 8.54 3 **Dy** [Xe] $4f^{10} 5d^0 6s^2$ Dysprosium	67 164.930 2600 1461 8.80 3 **Ho** [Xe]$4f^{11} 5d^0 6s^2$ Holmium	68 167.26 2900 1497 9.05 3 **Er** [Xe] $4f^{12} 5d^0 6s^2$ Erbium	69 168.934 1727 1545 9.33 3,2 **Tm** [Xe] $4f^{13} 5d^0 6s^2$ Thulium	70 173.04 1427 824 6.98 3,2 **Yb** [Xe]$4f^{14} 5d^0 6s^2$ Ytterbium	71 174.97 3327 1652 9.84 3 **Lu** [Xe] $4f^{14} 5d^1$ $6s^2$ Lutetium
★★	90 232.038 3850 1750 11.7 4 **Th** [Rn] $5F^0$ $6d^2$ $7s^2$ Thorium	91 (231) — (1230) 15.4 5,4 **Pa** [Rn]$5f^2 6d^1 7s^2$ Protactinium	92 238.03 3818 1132 19.07 6,5,4,3 **U** [Rn]$5f^3 6d^1 7s^2$ Uranium	93 (237) — 637 19.5 6,5,4,3 **Np** [Rn] $5f^4$ $6d^1$ $7s^2$ Neptunium	94 (242) — 3235 640 — 6,5,4,3 **Pu** [Rn]$5f^6 6d^0 7s^2$ Plutonium	95 (243) — — 11.7 6,5,4, 3 **Am** [Rn]$5f^7 6d^0 7s^2$ Americium	96 (247) — — — 3 **Cm** [Rn]$5f^7 6d^1 7s^2$ Curium	97 (247) — — — 4,3 **Bk** [Rn] $5F^9$ $6d^0$ $7s^2$ Berkelium	98 (249) — — — 3 **Cf** [Rn] $5f^{10}$ $6d^0$ $7s^2$ Californium	99 (254) — — — — **Es** [Rn] $5f^{11}$ $6d^0$ $7s^2$ Einsteinium	100 (253) — — — — **Fm** [Rn] $5f^{12}$ $6d^0$ $7s^2$ Fermium	101 (256) — — — — **Md** [Rn] $5f^{13}$ $6d^0$ $7s^2$ Mendelevium	102 (254) — — — — **No** [Rn] $5f^{14}$ $6d^0$ $7s^2$ Nobelium	103 (257) — — — — **Lw** [Rn] $5f^{14}$ $6d^1$ $7s^2$ Lawrencium



©Copyright 1962
©Copyright 1964
©Copyright 1965
©Copyright 1966
©Copyright 1968 SARGENT-WELCH SCIENTIFIC COMPANY

NOTES:

(1) Black — solid.
Red — gas.
Blue — liquid.
Outline — synthetically prepared.

(2) Based upon carbon – 12. ( ) indicates most stable or best known isotope.

(3) Values for gaseous elements are for liquids at the boiling point.

SARGENT-WELCH
SARGENT-WELCH SCIENTIFIC COMPANY
7300 LINDER AVENUE, SKOKIE, ILLINOIS 60076
CHICAGO • CINCINNATI • CLEVELAND • DETROIT • DALLAS • DENVER
BIRMINGHAM • SPRINGFIELD, N. J. • ANAHEIM, CALIF. • TORONTO, CANADA

The University of the State of New York
THE STATE EDUCATION DEPARTMENT
Albany, New York 12234

Reference Tables for Chemistry

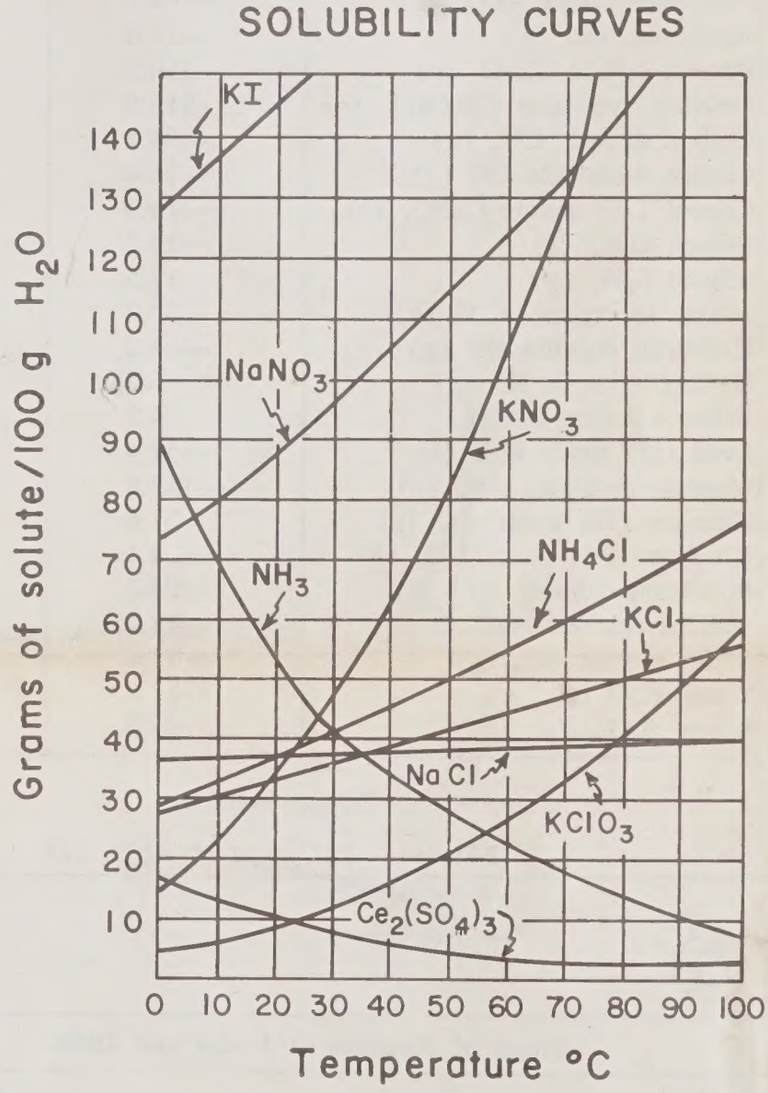
A

DENSITY AND BOILING POINTS OF SOME COMMON GASES

Name		*Density grams/liter at STP**	*Boiling Point (at 1 atm) K*
Air	—	1.29	—
Ammonia	NH_3	0.771	240
Carbon dioxide	CO_2	1.98	195
Carbon monoxide	CO	1.25	82
Chlorine	Cl_2	3.21	172
Hydrogen	H_2	0.0899	20
Hydrogen chloride	HCl	1.64	188
Hydrogen sulfide	H_2S	1.54	212
Methane	CH_4	0.714	109
Nitrogen	N_2	1.25	77
Nitrogen (II) oxide	NO	1.34	121
Oxygen	O_2	1.43	90
Sulfur dioxide	SO_2	2.93	263

*STP is defined as 273K or 0°C and 1 atm or 760 torr

B



C

TABLE OF SOLUBILITIES IN WATER

i — nearly insoluble
ss — slightly soluble
s — soluble
d — decomposes
n —not isolated

	acetate	bromide	carbonate	chloride	chromate	hydroxide	iodide	nitrate	phosphate	sulfate	sulfide
Aluminum	ss	s	n	s	n	i	s	s	i	s	d
Ammonium	s	s	s	s	s	s	s	s	s	s	s
Barium	s	s	i	s	i	s	s	s	i	i	d
Calcium	s	s	i	s	s	ss	s	s	i	ss	d
Copper II	s	s	i	s	i	i	d	s	i	s	i
Iron II	s	s	i	s	n	i	s	s	i	s	i
Iron III	s	s	n	s	i	i	s	s	i	ss	d
Lead	s	ss	i	ss	i	i	ss	s	i	i	i
Magnesium	s	s	i	s	s	i	s	s	i	s	d
Mercury I	ss	i	i	i	ss	n	i	s	i	ss	i
Mercury II	s	ss	i	s	ss	i	i	s	i	d	i
Potassium	s	s	s	s	s	s	s	s	s	s	s
Silver	ss	i	i	i	ss	n	i	s	i	ss	i
Sodium	s	s	s	s	s	s	s	s	s	s	s
Zinc	s	s	i	s	s	i	s	s	i	s	i

D

SELECTED POLYATOMIC IONS

$[Ag(NH_3)_2]^+$	diammine silver	MnO_4^{2-}	manganate
CH_3COO^-	acetate	NH_4^+	ammonium
CN^-	cyanide	NO_2^-	nitrite
CO_3^{2-}	carbonate	NO_3^-	nitrate
$C_2O_4^{2-}$	oxalate	OH^-	hydroxide
ClO_3^-	chlorate	PO_4^{3-}	phosphate
CrO_4^{2-}	chromate	SCN^-	thiocyanate
$Cr_2O_7^{2-}$	dichromate	SO_3^{2-}	sulfite
Hg_2^{2+}	mercury (I)	SO_4^{2-}	sulfate
MnO_4^-	permanganate	$S_2O_3^{2-}$	thiosulfate

reaction with O_2 is a combustion

the lower the $\triangle H$ the more stable

(E)

Standard Energies of Formation of Compounds at 1 atm and 298 K		
Compound	*Heat (Enthalpy) of Formation kcal/mole* ($\triangle H_f^\circ$)	*Free Energy of Formation kcal/mole* ($\triangle G_f^\circ$)
Aluminum oxide Al_2O_3 (s)	—399.1	—376.8
Ammonia NH_3 (g)	—11.0	—4.0
Barium sulfate $BaSO_4$ (s)	—350.2	—323.4
Calcium hydroxide $Ca(OH)_2$ (s)	—235.8	—214.3
Carbon dioxide CO_2 (g)	—94.1	—94.3
Carbon monoxide CO (g)	—26.4	—32.8
Copper (II) sulfate $CuSO_4$ (s)	—184.0	—158.2
Ethane C_2H_6 (g)	—20.2	—7.9
Ethene C_2H_4 (g)	12.5	16.3
Ethyne (acetylene) C_2H_2 (g)	54.2	50.0
Hydrogen fluoride HF (g)	—64.2	—64.7
Hydrogen iodide HI (g)	6.2	0.3
Iodine chloride ICl (g)	4.2	—1.3
Lead (II) oxide PbO (s)	—52.4	—45.3
Magnesium oxide MgO (s)	—143.8	—136.1
Nitrogen (II) oxide NO (g)	21.6	20.7
Nitrogen (IV) oxide NO_2 (g)	8.1	12.4
Potassium chloride KCl (s)	—104.2	—97.6
Sodium chloride NaCl (s)	—98.2	—91.8
Sulfur dioxide SO_2 (g)	—71.0	—71.8
Water H_2O (g)	—57.8	—54.6
Water H_2O (ℓ)	—68.3	—56.7

Sample equation

$$2Al\ (s) + \tfrac{3}{2}O_2\ (g) \rightarrow Al_2O_3\ (s)$$

+ endothermic
- epothermic

For a reaction to take place spontaneasly if ΔG is —

$H_2 + I_2 \longrightarrow 2HI + 2(-6.2)$

or $6.2 + \frac{1}{2}H_2 + I_2 \rightarrow HI$

Heat per mole of product

(F)

SELECTED RADIOISOTOPES		
Nuclide	*Half-Life*	*Particle Emission*
^{14}C	5730 y	β^-
^{60}Co	5.3 y	β^-
^{137}Cs	30.23 y	β^-
^{220}Fr	27.5 s	α
^{3}H	12.26 y	β^-
^{131}I	8.07 d	β^-
^{40}K	1.28×10^9 y	β^+
^{42}K	12.4 h	β^-
^{32}P	14.3 d	β^-
^{226}Ra	1600 y	α
^{90}Sr	28.1 y	β^-
^{235}U	7.1×10^8 y	α
^{238}U	4.51×10^9 y	α

y = years; d = days; h = hours; s = seconds

(G)

Heats of Reaction at 1 atm and 298K	
Reaction	$\triangle H$ (kcal)
$CH_4\ (g) + 2O_2\ (g) \rightarrow CO_2\ (g) + 2H_2O\ (\ell)$	—212.8
$C_3H_8\ (g) + 5O_2\ (g) \rightarrow 3CO_2\ (g) + 4H_2O\ (\ell)$	—530.6
$CH_3OH\ (\ell) + \frac{3}{2}O_2\ (g) \rightarrow CO_2\ (g) + 2H_2O\ (\ell)$	—173.6
$C_6H_{12}O_6\ (s) + 6O_2\ (g) \rightarrow 6CO_2\ (g) + 6H_2O\ (\ell)$	—669.9
$CO\ (g) + \frac{1}{2}O_2\ (g) \rightarrow CO_2\ (g)$	—67.7
$NaOH\ (s) \xrightarrow{H_2O} Na^+\ (aq) + OH^-\ (aq)$	—10.6
$NH_4Cl\ (s) \xrightarrow{H_2O} NH_4^+\ (aq) + Cl^-\ (aq)$	+3.5
$H^+\ (aq) + OH^-\ (aq) \rightarrow H_2O\ (\ell)$	—13.8

— Δ is exothermic

(H)

SYMBOLS USED IN NUCLEAR CHEMISTRY		
electron	$^{0}_{-1}e$	β^-
positron	$^{0}_{+1}e$	β^+
proton	$^{1}_{1}H$	p
alpha particle	$^{4}_{2}He$	α
neutron	$^{1}_{0}n$	n
gamma radiation		γ

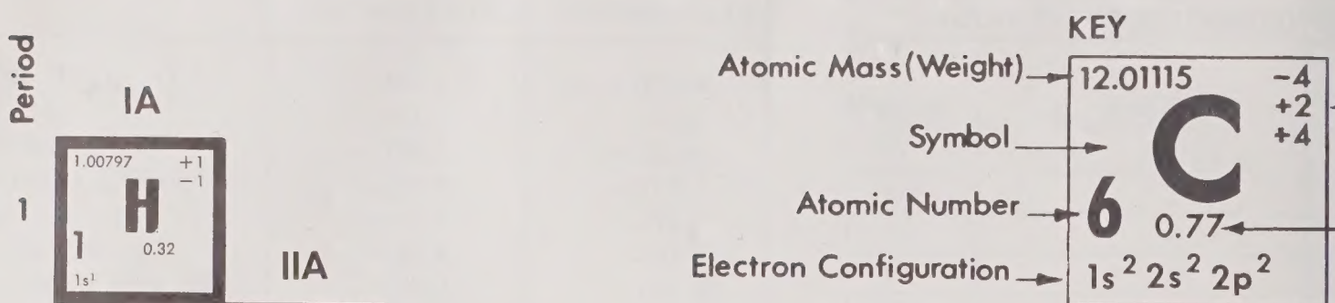
DENVER
CANADA
1976

Notes:

$-\bar{E}$ volts = spontanios
cathode = − cation = +
anode = + anion ion = −

Periodic Table of the E

Relative aton
$^{12}C = 12.000$



Period	IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIII
1	1.00797 +1 −1 **H** 1 0.32 $1s^1$							
2	6.939 +1 **Li** 3 1.23 $1s^2 2s^1$	9.0122 +2 **Be** 4 0.89 $1s^2 2s^2$						
3	22.9898 +1 **Na** 11 1.54 [Ne] $3s^1$	24.312 +2 **Mg** 12 1.36 [Ne] $3s^2$						
4	39.102 +1 **K** 19 2.03 [Ar] $4s^1$	40.08 +2 **Ca** 20 1.74 [Ar] $4s^2$	44.956 +3 **Sc** 21 1.44 [Ar] $3d^1 4s^2$	47.90 +2 +3 +4 **Ti** 22 1.32 [Ar] $3d^2 4s^2$	50.942 +2 +3 +4 +5 **V** 23 1.22 [Ar] $3d^3 4s^2$	51.996 +2 +3 +6 **Cr** 24 1.18 [Ar] $3d^5 4s^1$	54.9380 +2 +3 +4 +7 **Mn** 25 1.17 [Ar] $3d^5 4s^2$	55.847 +2 +3 **Fe** 26 1.17 [Ar] $3d^6 4s^2$	58.9332 **Co** 27 1.16 [Ar] $3d^7 4s^2$
5	85.47 +1 **Rb** 37 2.16 [Kr] $5s^1$	87.62 +2 **Sr** 38 1.91 [Kr] $5s^2$	88.905 +3 **Y** 39 1.62 [Kr] $4d^1 5s^2$	91.22 +4 **Zr** 40 1.45 [Kr] $4d^2 5s^2$	92.906 +3 +5 **Nb** 41 1.34 [Kr] $4d^4 5s^1$	95.94 +3 +6 **Mo** 42 1.30 [Kr] $4d^5 5s^1$	98.9062 +4 +6 +7 **Tc** 43 1.27 [Kr] $4d^6 5s^1$	101.07 +3 **Ru** 44 1.25 [Kr] $4d^7 5s^1$	102.905 **Rh** 45 1.25 [Kr] $4d^8 5s^1$
6	132.905 +1 **Cs** 55 2.35 [Xe] $6s^1$	137.34 +2 **Ba** 56 1.98 [Xe] $6s^2$	138.91 +3 **La** 57 1.69 [Xe] $5d^1 6s^2$	178.49 +4 **Hf** 72 1.44 [Xe] $4f^{14} 5d^2 6s^2$	180.948 +5 **Ta** 73 1.34 [Xe] $4f^{14} 5d^3 6s^2$	183.85 +6 **W** 74 1.30 [Xe] $4f^{14} 5d^4 6s^2$	186.2 +4 +6 +7 **Re** 75 1.28 [Xe] $4f^{14} 5d^5 6s^2$	190.2 +3 +4 **Os** 76 1.26 [Xe] $4f^{14} 5d^6 6s^2$	192.2 **Ir** 77 1.27 [Xe] $4f^{14} 5d^7 6s^2$
7	(223) +1 **Fr** 87 [Rn] $7s^1$	(226) +2 **Ra** 88 2.20 [Rn] $7s^2$	(227) +3 **Ac** 89 2.0 [Rn] $6d^1 7s^2$	104	105				

GROUPS

Transition Elements

Numbers in parentheses are mass numbers of most stable or most common isotope.

Lanthanide Series	140.12 +3 +4 **Ce** 58 1.65	140.907 +3 **Pr** 59 1.64	144.24 +3 **Nd** 60 1.64	(145) +3 **Pm** 61 1.63	150.35 +2 +3 **Sm** 62 1.62	151.96 +2 +3 **Eu** 63 1.85	157.2 64
Actinide Series	232.038 +4 **Th** 90 1.65	231.036 +4 +5 **Pa** 91	238.03 +3 +4 +5 +6 **U** 92 1.42	237.048 +3 +4 +5 +6 **Np** 93	(244) +3 +4 +5 +6 **Pu** 94	(243) +3 +4 +5 +6 **Am** 95	(247) 96

ements

masses are based on

~ us - is low
~ price - is high

d Oxidation States

nt Atomic Radius (Å)

Non Metals

GROUPS

	IIIA	IVA	VA	VIA	VIIA	O
						4.0026 0 **He** 2 0.31 $1s^2$
	10.811 +3 **B** 5 0.82 $1s^2 2s^2 2p^1$	12.01115 −4 +2 +4 **C** 6 0.77 $1s^2 2s^2 2p^2$	14.0067 −3 −2 −1 +1 +2 +3 +4 +5 **N** 7 0.75 $1s^2 2s^2 2p^3$	15.9994 −2 **O** 8 0.73 $1s^2 2s^2 2p^4$	18.9984 −1 **F** 9 0.72 $1s^2 2s^2 2p^5$	20.183 0 **Ne** 10 0.71 $1s^2 2s^2 2p^6$
	26.9815 +3 **Al** 13 1.18 [Ne] $3s^2 3p^1$	28.086 −4 +2 +4 **Si** 14 1.11 [Ne] $3s^2 3p^2$	30.9738 −3 +3 +5 **P** 15 1.06 [Ne] $3s^2 3p^3$	32.064 −2 +4 +6 **S** 16 1.02 [Ne] $3s^2 3p^4$	35.453 −1 +1 +3 +5 +7 **Cl** 17 0.99 [Ne] $3s^2 3p^5$	39.948 0 **Ar** 18 0.98 [Ne] $3s^2 3p^6$

IB	IIB							
58.71 +2 +3 **Ni** 28 1.15 [Ar] $3d^8 4s^2$	63.54 +1 +2 **Cu** 29 1.17 [Ar] $3d^{10} 4s^1$	65.37 +2 **Zn** 30 1.25 [Ar] $3d^{10} 4s^2$	69.72 +3 **Ga** 31 1.26 [Ar] $3d^{10} 4s^2 4p^1$	72.59 +2 +4 **Ge** 32 1.22 [Ar] $3d^{10} 4s^2 4p^2$	74.9216 −3 +3 +5 **As** 33 1.20 [Ar] $3d^{10} 4s^2 4p^3$	78.96 −2 +4 +6 **Se** 34 1.17 [Ar] $3d^{10} 4s^2 4p^4$	79.909 −1 +1 +5 **Br** 35 1.14 [Ar] $3d^{10} 4s^2 4p^5$	83.80 0 **Kr** 36 1.12 [Ar] $3d^{10} 4s^2 4p^6$
106.4 +2 +4 **Pd** 46 1.28 [Kr] $4d^{10} 5s^0$	107.870 +1 **Ag** 47 1.34 [Kr] $4d^{10} 5s^1$	112.40 +2 **Cd** 48 1.48 [Kr] $4d^{10} 5s^2$	114.82 +3 **In** 49 1.44 [Kr] $4d^{10} 5s^2 5p^1$	118.69 +2 +4 **Sn** 50 1.40 [Kr] $4d^{10} 5s^2 5p^2$	121.75 −3 +3 +5 **Sb** 51 1.40 [Kr] $4d^{10} 5s^2 5p^3$	127.60 −2 +4 +6 **Te** 52 1.36 [Kr] $4d^{10} 5s^2 5p^4$	126.9044 −1 +1 +5 +7 **I** 53 1.33 [Kr] $4d^{10} 5s^2 5p^5$	131.30 0 **Xe** 54 1.31 [Kr] $4d^{10} 5s^2 5p^6$
195.09 +2 +4 **Pt** 78 1.30 [Xe] $4f^{14} 5d^9 6s^1$	196.967 +1 +3 **Au** 79 1.34 [Xe] $4f^{14} 5d^{10} 6s^1$	200.59 +1 +2 **Hg** 80 1.49 [Xe] $4f^{14} 5d^{10} 6s^2$	204.37 +1 +3 **Tl** 81 1.48 [Xe] $4f^{14} 5d^{10} 6s^2 6p^1$	207.19 +2 +4 **Pb** 82 1.47 [Xe] $4f^{14} 5d^{10} 6s^2 6p^2$	208.980 +3 +5 **Bi** 83 1.46 [Xe] $4f^{14} 5d^{10} 6s^2 6p^3$	(209) +2 +4 **Po** 84 1.46 [Xe] $4f^{14} 5d^{10} 6s^2 6p^4$	(210) **At** 85 1.45 [Xe] $4f^{14} 5d^{10} 6s^2 6p^5$	(222) 0 **Rn** 86 [Xe] $4f^{14} 5d^{10} 6s^2 6p^6$

+3 **d** 1.62	158.924 +3 **Tb** 65 1.61	162.50 +3 **Dy** 66 1.60	164.930 +3 **Ho** 67 1.58	167.26 +3 **Er** 68 1.58	168.934 +3 **Tm** 69 1.58	173.04 +2 +3 **Yb** 70 1.70	174.97 +3 **Lu** 71 1.56
+3 **n**	(247) +3 +4 **Bk** 97	(251) +3 **Cf** 98	(254) **Es** 99	(257) **Fm** 100	(256) **Md** 101	(254) **No** 102	(257) **Lr** 103

Notes:

(I)

Ionization Energies and Electronegativities

IA							0
313 H 2.1	← First Ionization Energy (kcal/mole of atoms) ← Electronegativity						567 He
	IIA	IIIA	IVA	VA	VIA	VIIA	
124 Li 1.0	215 Be 1.5	191 B 2.0	260 C 2.5	336 N 3.0	314 O 3.5	402 F 4.0	497 Ne
119 Na 0.9	176 Mg 1.2	138 Al 1.5	188 Si 1.8	254 P 2.1	239 S 2.5	300 Cl 3.0	363 Ar
100 K 0.8	141 Ca 1.0	138 Ga 1.6	187 Ge 1.8	231 As 2.0	225 Se 2.4	273 Br 2.8	323 Kr
96 Rb 0.8	131 Sr 1.0	133 In 1.7	169 Sn 1.8	199 Sb 1.9	208 Te 2.1	241 I 2.5	280 Xe
90 Cs 0.7	120 Ba 0.9	141 Tl 1.8	171 Pb 1.8	185 Bi 1.9	Po 2.0	At 2.2	248 Rn
Fr 0.7	Ra						

(J)

RELATIVE STRENGTHS OF ACIDS IN AQUEOUS SOLUTION at 1 atm AND 298 K

Conjugate Pairs *ACID* ⟶ *BASE*	K_a
$HI \longrightarrow H^+ + I^-$	very large
$HBr \longrightarrow H^+ + Br^-$	very large
$HCl \longrightarrow H^+ + Cl^-$	very large
$HNO_3 \longrightarrow H^+ + NO_3^-$	very large
$H_2SO_4 \longrightarrow H^+ + HSO_4^-$	large
$H_2O + SO_2 \longrightarrow H^+ + HSO_3^-$	1.7×10^{-2}
$HSO_4^- \longrightarrow H^+ + SO_4^{2-}$	1.3×10^{-2}
$H_3PO_4 \longrightarrow H^+ + H_2PO_4^-$	7.1×10^{-3}
$Fe(H_2O)_6^{3+} \longrightarrow H^+ + Fe(H_2O)_5(OH)^{2+}$	6.0×10^{-3}
$HF \longrightarrow H^+ + F^-$	6.7×10^{-4}
$HNO_2 \longrightarrow H^+ + NO_2^-$	5.1×10^{-4}
$Cr(H_2O)_6^{3+} \longrightarrow H^+ + Cr(H_2O)_5(OH)^{2+}$	1.0×10^{-4}
$CH_3COOH \longrightarrow H^+ + CH_3COO^-$	1.8×10^{-5}
$Al(H_2O)_6^{3+} \longrightarrow H^+ + Al(H_2O)_5(OH)^{2+}$	1.0×10^{-5}
$H_2O + CO_2 \longrightarrow H^+ + HCO_3^-$	4.4×10^{-7}
$H_2S \longrightarrow H^+ + HS^-$	1.0×10^{-7}
$H_2PO_4^- \longrightarrow H^+ + HPO_4^{2-}$	6.3×10^{-8}
$HSO_3^- \longrightarrow H^+ + SO_3^{2-}$	6.2×10^{-8}
$NH_4^+ \longrightarrow H^+ + NH_3$	5.7×10^{-10}
$HCO_3^- \longrightarrow H^+ + CO_3^{2-}$	4.7×10^{-11}
$HPO_4^{2-} \longrightarrow H^+ + PO_4^{3-}$	4.4×10^{-13}
$HS^- \longrightarrow H^+ + S^{2-}$	1.3×10^{-13}
$OH^- \longrightarrow H^+ + O^{2-}$	$< 10^{-36}$
$NH_3 \longrightarrow H^+ + NH_2^-$	very small

(K)

Constants for Various Equilibria at 1 atm and 298 K

$H_2O = H^+(aq) + OH^-(aq)$	$K_w = 1.0 \times 10^{-14}$
$CH_3COO^-(aq) + H_2O = CH_3COOH(aq) + OH^-(aq)$	$K_b = 5.6 \times 10^{-10}$
$NH_3(aq) + H_2O = NH_4^+(aq) + OH^-(aq)$	$K_b = 1.8 \times 10^{-5}$
$CO_3^{2-}(aq) + H_2O = HCO_3^-(aq) + OH^-(aq)$	$K_b = 2.1 \times 10^{-4}$
$Ag(NH_3)_2^+(aq) = Ag^+(aq) + 2NH_3(aq)$	$K_{eq} = 6.3 \times 10^{-8}$
$N_2(g) + 3H_2(g) = 2NH_3(g)$	$K_{eq} = 6.7 \times 10^{5}$
$H_2(g) + I_2(g) = 2HI(g)$	$K_{eq} = 3.5 \times 10^{-1}$

Compound	K_{sp}	*Compound*	K_{sp}
AgCl	1.6×10^{-10}	$PbCl_2$	1.6×10^{-5}
AgBr	7.7×10^{-13}	$PbCrO_4$	1.8×10^{-14}
AgI	1.5×10^{-16}	PbI_2	1.4×10^{-8}
$BaSO_4$	1.1×10^{-10}	ZnS	1.6×10^{-23}

(L)

STANDARD ELECTRODE POTENTIALS

Ionic Concentrations 1 M Water at 298 K, 1 atm

Half-Reaction	$E°$ *(volts)*
$F_2(g) + 2e^- \longrightarrow 2F^-$	+2.87
$MnO_4^- + 8H^+ + 5e^- \longrightarrow Mn^{2+} + 4H_2O$	+1.52
$Au^{3+} + 3e^- \longrightarrow Au(s)$	+1.50
$Cl_2(g) + 2e^- \longrightarrow 2Cl^-$	+1.36
$Cr_2O_7^{2-} + 14H^+ + 6e^- \longrightarrow 2Cr^{3+} + 7H_2O$	+1.33
$MnO_2(s) + 4H^+ + 2e^- \longrightarrow Mn^{2+} + 2H_2O$	+1.28
$\frac{1}{2}O_2(g) + 2H^+ + 2e^- \longrightarrow H_2O$	+1.23
$Br_2(\ell) + 2e^- \longrightarrow 2Br^-$	+1.06
$NO_3^- + 4H^+ + 3e^- \longrightarrow NO(g) + 2H_2O$	+0.96
$\frac{1}{2}O_2(g) + 2H^+(10^{-7}M) + 2e^- \longrightarrow H_2O$	+0.82
$Ag^+ + e^- \longrightarrow Ag(s)$	+0.80
$\frac{1}{2}Hg_2^{2+} + e^- \longrightarrow Hg(\ell)$	+0.79
$Hg^{2+} + 2e^- \longrightarrow Hg(\ell)$	+0.78
$NO_3^- + 2H^+ + e^- \longrightarrow NO_2(g) + H_2O$	+0.78
$Fe^{3+} + e^- \longrightarrow Fe^{2+}$	+0.77
$I_2(s) + 2e^- \longrightarrow 2I^-$	+0.53
$Cu^+ + e^- \longrightarrow Cu(s)$	+0.52
$Cu^{2+} + 2e^- \longrightarrow Cu(s)$	+0.34
$SO_4^{2-} + 4H^+ + 2e^- \longrightarrow SO_2(g) + 2H_2O$	+0.17
$Sn^{4+} + 2e^- \longrightarrow Sn^{2+}$	+0.15
$2H^+ + 2e^- \longrightarrow H_2(g)$	0.00
$Pb^{2+} + 2e^- \longrightarrow Pb(s)$	−0.13
$Sn^{2+} + 2e^- \longrightarrow Sn(s)$	−0.14
$Ni^{2+} + 2e^- \longrightarrow Ni(s)$	−0.25
$Co^{2+} + 2e^- \longrightarrow Co(s)$	−0.28
$2H^+(10^{-7}M) + 2e^- \longrightarrow H_2(g)$	−0.41
$Fe^{2+} + 2e^- \longrightarrow Fe(s)$	−0.44
$Cr^{3+} + 3e^- \longrightarrow Cr(s)$	−0.74
$Zn^{2+} + 2e^- \longrightarrow Zn(s)$	−0.76
$2H_2O + 2e^- \longrightarrow 2OH^- + H_2(g)$	−0.83
$Mn^{2+} + 2e^- \longrightarrow Mn(s)$	−1.18
$Al^{3+} + 3e^- \longrightarrow Al(s)$	−1.66
$Mg^{2+} + 2e^- \longrightarrow Mg(s)$	−2.37
$Na^+ + e^- \longrightarrow Na(s)$	−2.71
$Ca^{2+} + 2e^- \longrightarrow Ca(s)$	−2.87
$Sr^{2+} + 2e^- \longrightarrow Sr(s)$	−2.89
$Ba^{2+} + 2e^- \longrightarrow Ba(s)$	−2.90
$Cs^+ + e^- \longrightarrow Cs(s)$	−2.92
$K^+ + e^- \longrightarrow K(s)$	−2.92
$Rb^+ + e^- \longrightarrow Rb(s)$	−2.93
$Li^+ + e^- \longrightarrow Li(s)$	−3.00

(M)

PHYSICAL CONSTANTS

Name	*Symbol*	*Values*
Speed of light	c	3.00×10^8 meters/sec
Avogadro number	N_A	6.02×10^{23} per mole
Universal Gas Constant	R	0.0821 liter·atm /mole·K 1.99 cal/mole·K 8.31 joule/mole·K
Planck's Constant	h	6.63×10^{-34} joule·sec 1.58×10^{-37} kcal·sec
Charge of electron	e	1.60×10^{-19} coulomb

Molal freezing point depression constant for $H_2O = 1.86C°$

Molal boiling point elevation constant for $H_2O = 0.52C°$

Atomic Mass Unit	1 amu $= 1.66 \times 10^{-24}$ g
Heat Equivalent	1 kcal $= 4.19 \times 10^3$ joule
Volume Standard	1 liter $= 1.00 \times 10^3$ cm^3
Angstrom Unit	1 Å $= 1.00 \times 10^{-10}$ meter
Electron Volt	1 ev $= 1.60 \times 10^{-19}$ joule

(N)

VAPOR PRESSURE OF WATER

°C	*torr (mm Hg)*	°C	*torr (mm Hg)*
0	4.6	26	25.2
5	6.5	27	26.7
10	9.2	28	28.3
15	12.8	29	30.0
16	13.6	30	31.8
17	14.5	40	55.3
18	15.5	50	92.5
19	16.5	60	149.4
20	17.5	70	233.7
21	18.7	80	355.1
22	19.8	90	525.8
23	21.1	100	760.0
24	22.4	105	906.1
25	23.8	110	1074.6

Summary of Equations Used in New York State Physics Course

Unit I MECHANICS

$\bar{v} = \frac{s}{t}$ $\quad \bar{v} = \frac{v_f + v_i}{2}$

$a = \frac{\Delta v}{\Delta t}$

$s = \frac{1}{2} at^2$

$v^2 = 2as$

$F = ma$

$w = mg$

$F_c = \frac{mv^2}{r}$ $\quad a_c = \frac{v^2}{r}$

$F\Delta t = \Delta mv$ $\quad m_1 v_1 = m_2 v_2$

$W = Fs$

$E_p = mgh$

$E_k = \frac{1}{2} mv^2$

$P = \frac{W}{t} = \frac{Fs}{t} = Fv$

$\Delta E_p = -\Delta E_k$

$T_k = t_c + 273$

$\Delta Q = mc\Delta t_c$

$Q_e = Q_g$

$Q_f = mH_f$

$Q_v = mH_v$

$F = \frac{Gm_1 m_2}{d^2}$

P = power

T_k = Kelvin temperature

t_c = Celsius temperature

Q = heat

Q_e = heat lost

Q_g = heat gained

c = specific heat

H_f = heat of fusion

H_v = heat of vaporization

v_i = initial speed

v_f = final speed

$\bar{v}$ = average speed

a = acceleration

s = distance

F = force

m = mass

g = acceleration of gravity

w = weight

F_c = centripetal force

r = radius of curvature

t = time

W = work

E_p = potential energy

E_k = kinetic energy

G = Universal gravitational constant

d = distance

a_c = centripetal acceleration

Unit 2 - WAVE PHENOMENA

$T = \frac{1}{f}$

$v = f\lambda$

$\frac{\sin \theta_1}{\sin \theta_2} = \frac{n_2}{n_1} = \frac{v_1}{v_2} = K$

$v = \frac{c}{n}$

$\sin \theta_c = \frac{1}{n}$

$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$

$\frac{s_o}{s_i} = \frac{d_o}{d_i}$

$\lambda = \frac{dx}{L}$ (first order)

T = period

f = frequency

v = speed

λ = wavelength

θ_1 = angle of incidence

θ_2 = angle of refraction

n = index of refraction

θ_c = critical angle

d_o = object to lens distance

d_i = image to lens distance

s_o = size of object

s_i = size of image

f = focal length

d = distance between slits

x = distance from central maximum to line

L = distance from slit to screen

K = relative index of refraction

1/4 + 1/4

Unit 3 - ELECTRICITY

$$F = k\frac{q_1 q_2}{d^2}$$

$$E = \frac{F}{q}$$

$$V = \frac{W}{q}$$

$$E = \frac{V}{d}$$

$$V = IR$$

$$P = VI = I^2R = \frac{V^2}{R}$$

$$W = Pt$$

$$JQ = VIt = I^2Rt = Pt$$

$$F = qvB$$

$$V = Blv$$

Series Circuits

$$I_t = I_1 = I_2 = I_3 = \ldots.$$

$$V_t = V_1 + V_2 + V_3 + \ldots.$$

$$R_t = R_1 + R_2 + R_3 + \ldots.$$

Parallel Circuits

$$I_t = I_1 + I_2 + I_3 + \ldots.$$

$$V_t = V_1 = V_2 = V_3 = \ldots.$$

$$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots.$$

F = force

q = charge

d = distance

E = electric field intensity

V = electric potential

I = current

R = resistance

P = power

t = time

W = energy

Q = heat

B = flux density

l = length of conductor

v = velocity

k = electrostatic constant

J = mechanical equivalent of heat

Unit 4 - ATOMIC AND NUCLEAR ENERGY

$$E = hf$$

$$E_k = hf - W_o$$

$$E_{photon} = E_i - E_f = hf$$

$$m_f = \frac{1}{2^n} m_i$$

$$E = mc^2$$

E = energy

h = Planck's constant

f = frequency

W_o = work function

E_k = kinetic energy of photoelectron

E_i = initial energy level

E_f = final energy level

m_f = final mass

m_i = initial mass

n = number of half lives

m = mass

c = speed of light

THE UNIVERSITY OF THE STATE OF NEW YORK
THE STATE EDUCATION DEPARTMENT
ALBANY, NEW YORK 12224

PHYSICS REFERENCE TABLES

LIST OF PHYSICAL CONSTANTS

Gravitational Constant (G)	6.67×10^{-11} newton-meters^2/kg^2
Acceleration of gravity (g) (near earth's surface)	9.81 meters/second^2
Speed of light (c)	3.00×10^{8} meters/second
Speed of sound at S.T.P.	3.31×10^{2} meters/second
Mechanical equivalent of heat	$J = 4.19 \times 10^{3}$ joules/kilocalorie
	$\frac{1}{J} = 2.39 \times 10^{-4}$ kilocalories/joule
Mass energy relationship	1 amu $= 9.31 \times 10^{2}$ Mev
Electrostatic constant	$k = 9.00 \times 10^{9}$ newton-meters^2/coul^2
Charge of the electron = 1 elementary charge	1.60×10^{-19} coulomb
One coulomb	6.25×10^{18} electrons
	6.25×10^{18} elementary charges
Electron volt (ev)	1.60×10^{-19} joule
Planck's Constant (h)	6.63×10^{-34} joule-second
Rest mass of the electron (m_e)	9.11×10^{-31} kilogram
Rest mass of the proton (m_p)	1.67×10^{-27} kilogram
Rest mass of the neutron (m_n)	1.67×10^{-27} kilogram

TRIGONOMETRIC FUNCTIONS

sine 0°	= .000
sine 30°	= .500
sine 45°	= .707
sine 60°	= .866
sine 90°	= 1.000

WAVELENGTHS OF LIGHT IN A VACUUM

VIOLET	$<4.5 \times 10^{-7}$ meters
BLUE	$4.5 - 5.0 \times 10^{-7}$ meters
GREEN	$5.0 - 5.7 \times 10^{-7}$ meters
YELLOW	$5.7 - 5.9 \times 10^{-7}$ meters
ORANGE	$5.9 - 6.1 \times 10^{-7}$ meters
RED	$>6.1 \times 10^{-7}$ meters

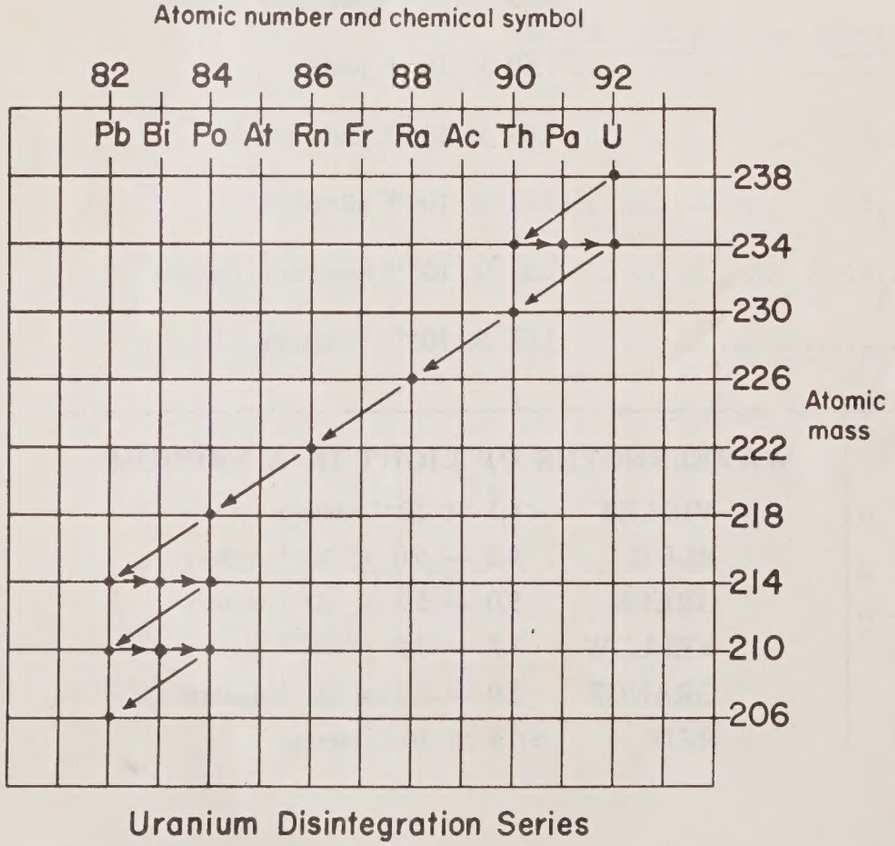
HEAT CONSTANTS

	Specific Heat (average)	*Melting Point*	*Boiling Point*	*Heat of Fusion*	*Heat of Vaporization*
	——	°C.	°C.	$\frac{\text{kcal}}{\text{kg}}$	$\frac{\text{kcal}}{\text{kg}}$
Alcohol, ethyl	0.58 (liq.)	—115	78	25	204
Aluminum	0.21 (sol.)	660	2057	77	2520
Ammonia	1.13 (liq.)	—78	—33	84	327
Copper	0.09 (sol.)	1083	2336	49	1150
Ice	0.50 (sol.)	0	—	80	—
Iron	0.11 (sol.)	1535	3000	7.9	1600
Lead	0.03 (sol.)	327	1620	5.9	207
Mercury	0.03 (liq.)	—39	357	2.8	71
Platinum	0.03 (sol.)	1774	4300	27	—
Silver	0.06 (sol.)	961	1950	26	565
Steam	0.48 (gas)	—	—	—	—
Water	1.00 (liq.)	—	100	—	540
Tungsten	0.04 (sol.)	3370	5900	43	—
Zinc	0.09 (sol.)	419	907	23	420

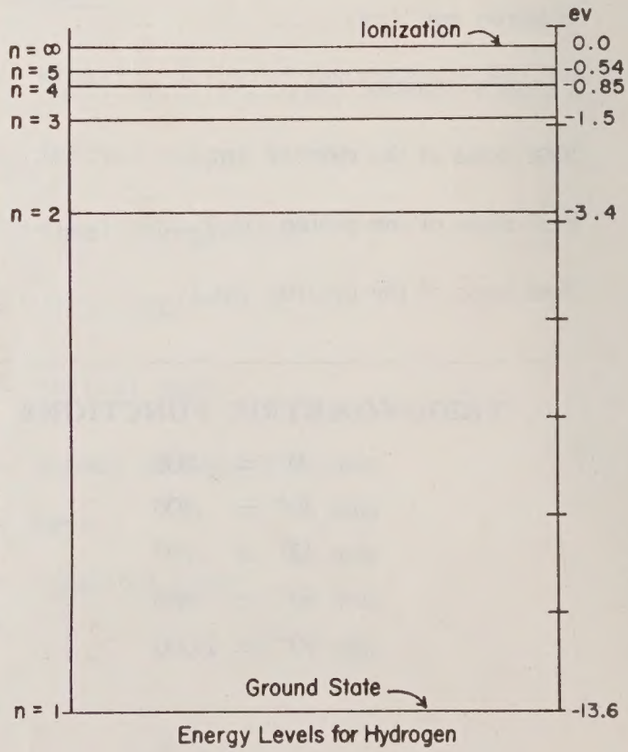
ABSOLUTE INDICES OF REFRACTION

($\lambda = 5.9 \times 10^{-7}$m.)

Air 1.00	Carbon Tetrachloride.. 1.46	Glycerol 1.47
Alcohol 1.36	Diamond 2.42	Lucite 1.50
Benzene 1.50	Glass, Crown..... 1.52	Quartz, Fused..... 1.46
Canada Balsam..... 1.53	Glass, Flint 1.61	Water 1.33



Uranium Disintegration Series



Energy Levels for Hydrogen